Aligning ARC split beam injector centering images: detecting objects with partial obstruction

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Abstract

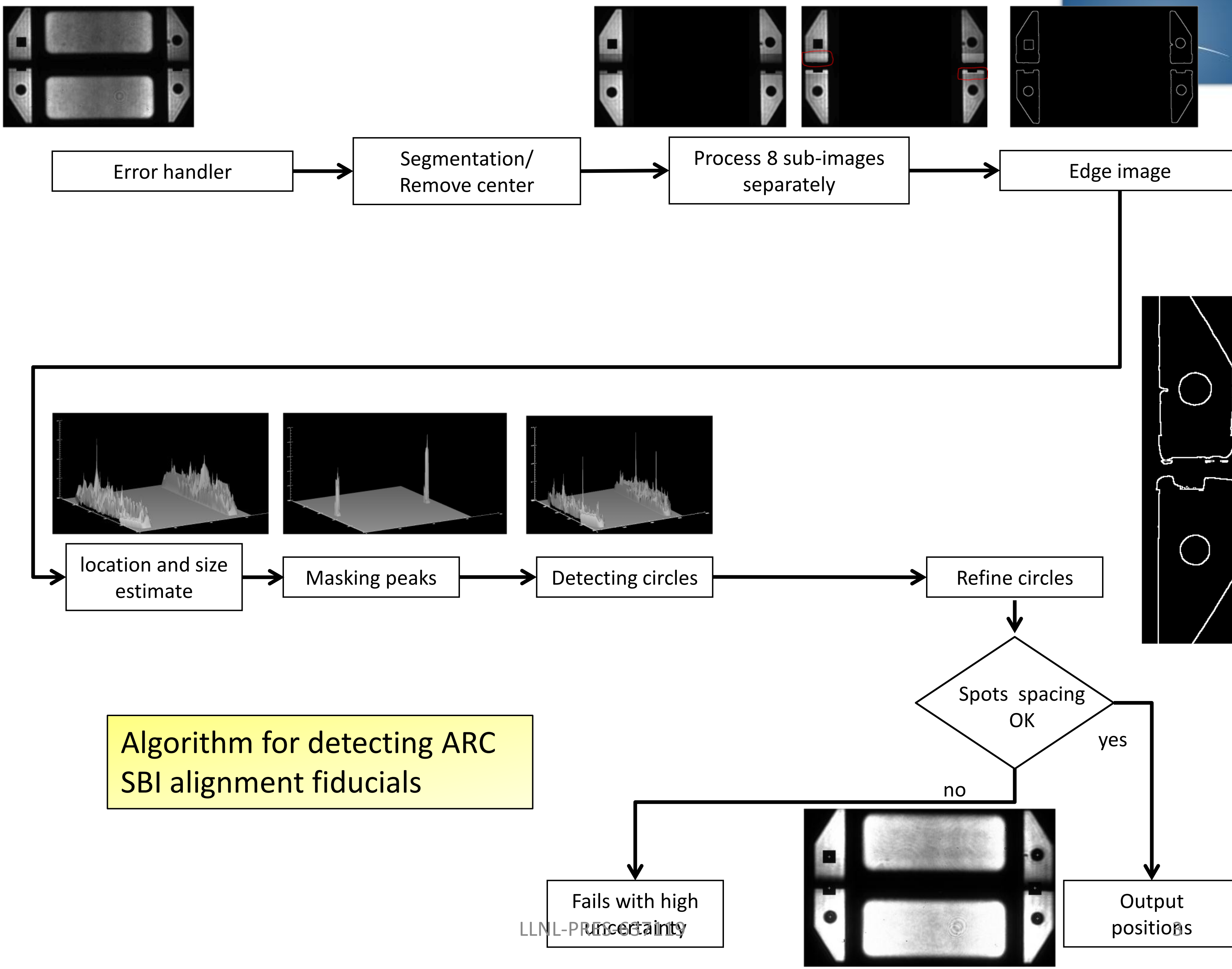
The National Ignition Facility (NIF) utilizes 192 beams, four of which are diverted to create the **Advanced Radiographic Capability (ARC)** by generating a sequence of *short laser pulses*. This backlighted beam after being converted to **X-ray** will create a radiographic **movie** and provide an unprecedented **insight** into the **imploding dynamics** and serve as a diagnostic for **tuning** the experimental parameters to achieve fusion.

The ARC beams need to be **aligned** precisely as it is guided through a series of **complex optical paths**. One such beam is the centering beam of the pre-amplifier module which due to a **split path obstructs** the central **square** alignment fiducials.

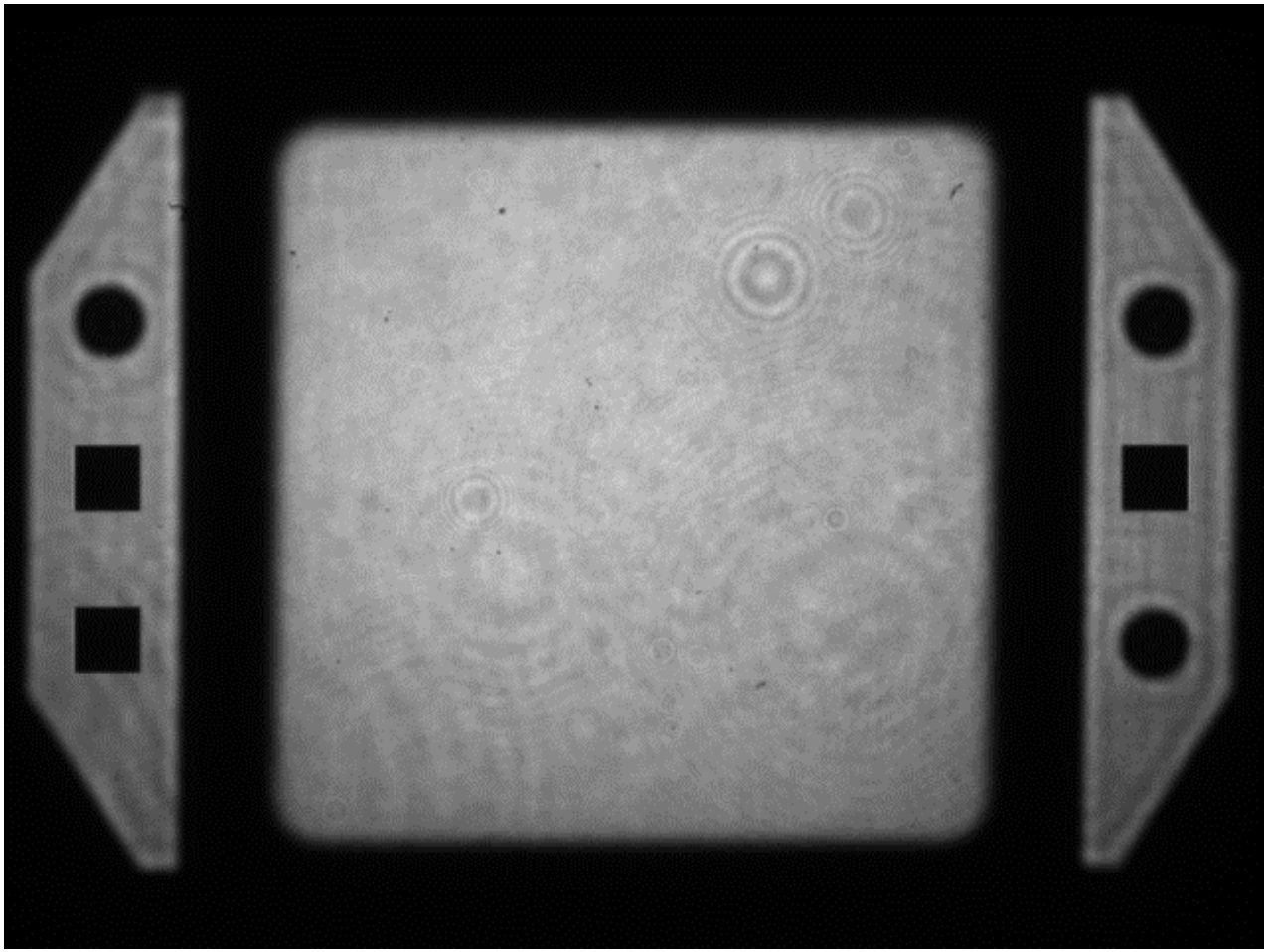
Image processing **algorithms** are used to process the images and calculate the **position** of various fiducials in the beam path. The **control** system uses results of the processing to **adjust** motorized **mirrors** within a series of control loops until pre-defined **alignment** criteria are satisfied.

We discuss the **algorithm** to process ARC split beam injector (SBI) centering images with **partial fiducial** information.

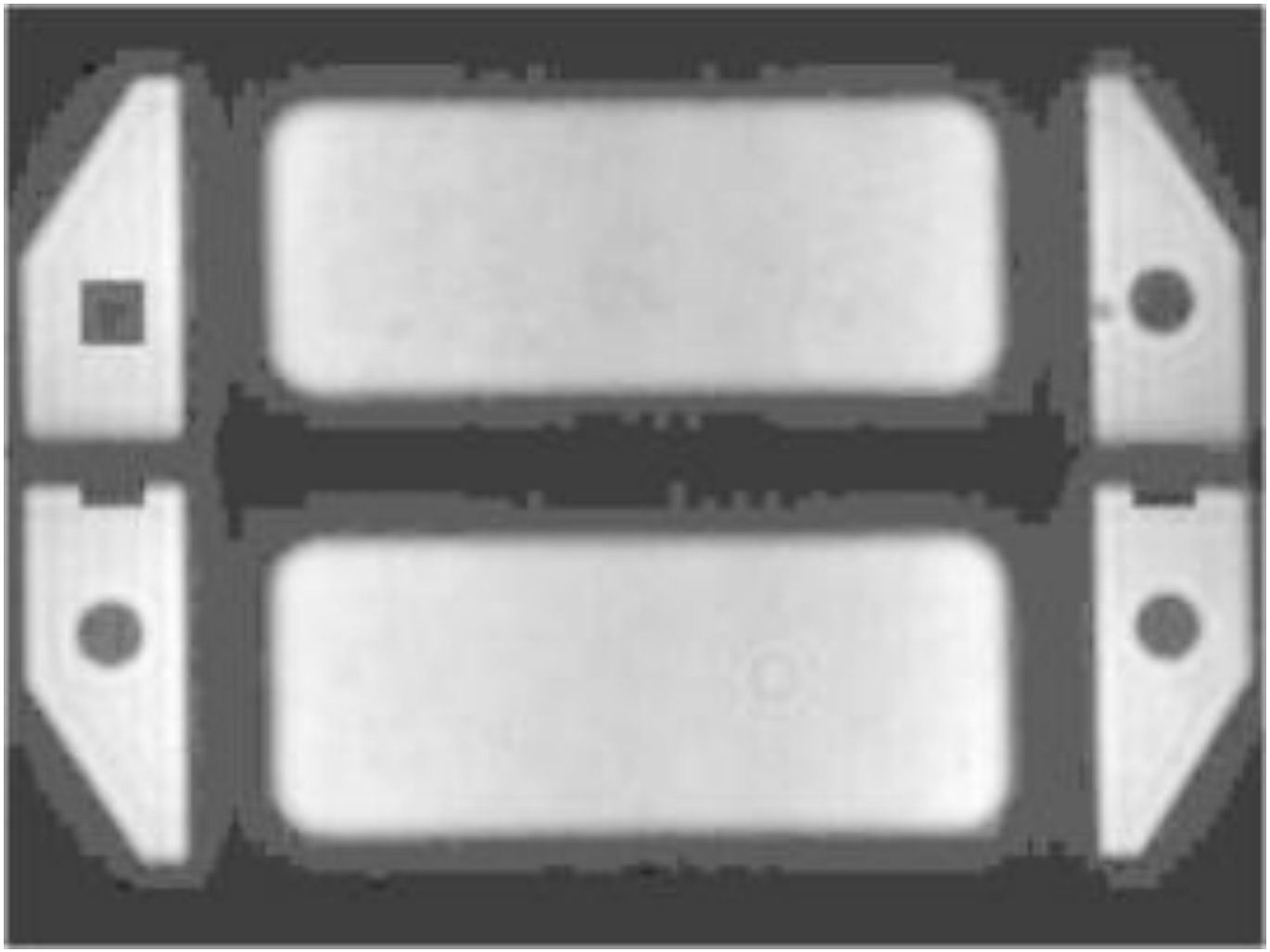
Algorithm for detecting ARC SBI alignment fiducials



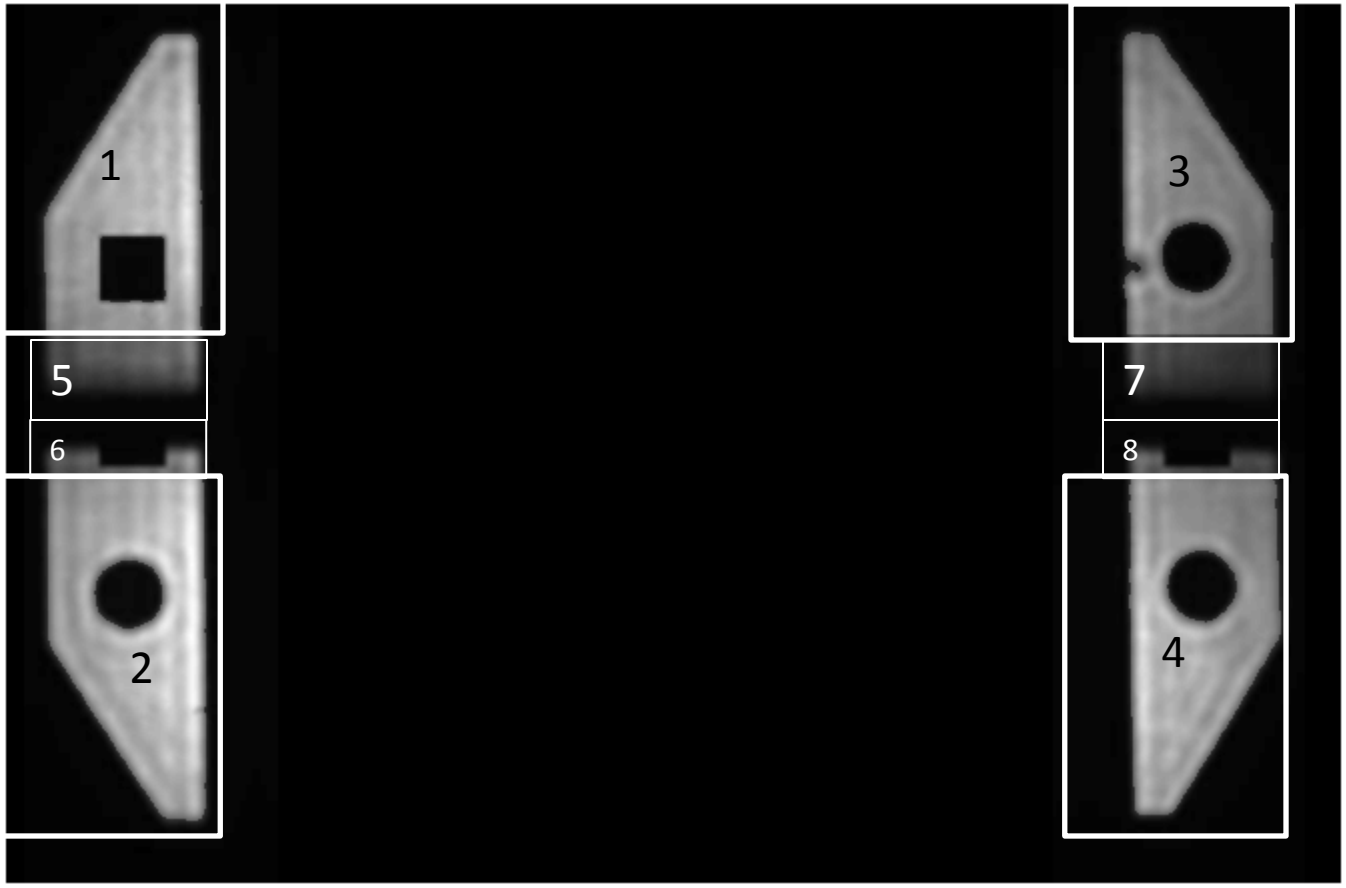
A PAM alignment image

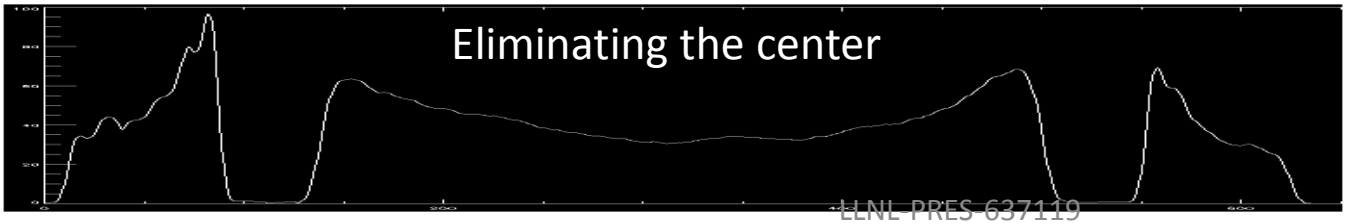


ARC SBI image: enhanced to show the low light levels

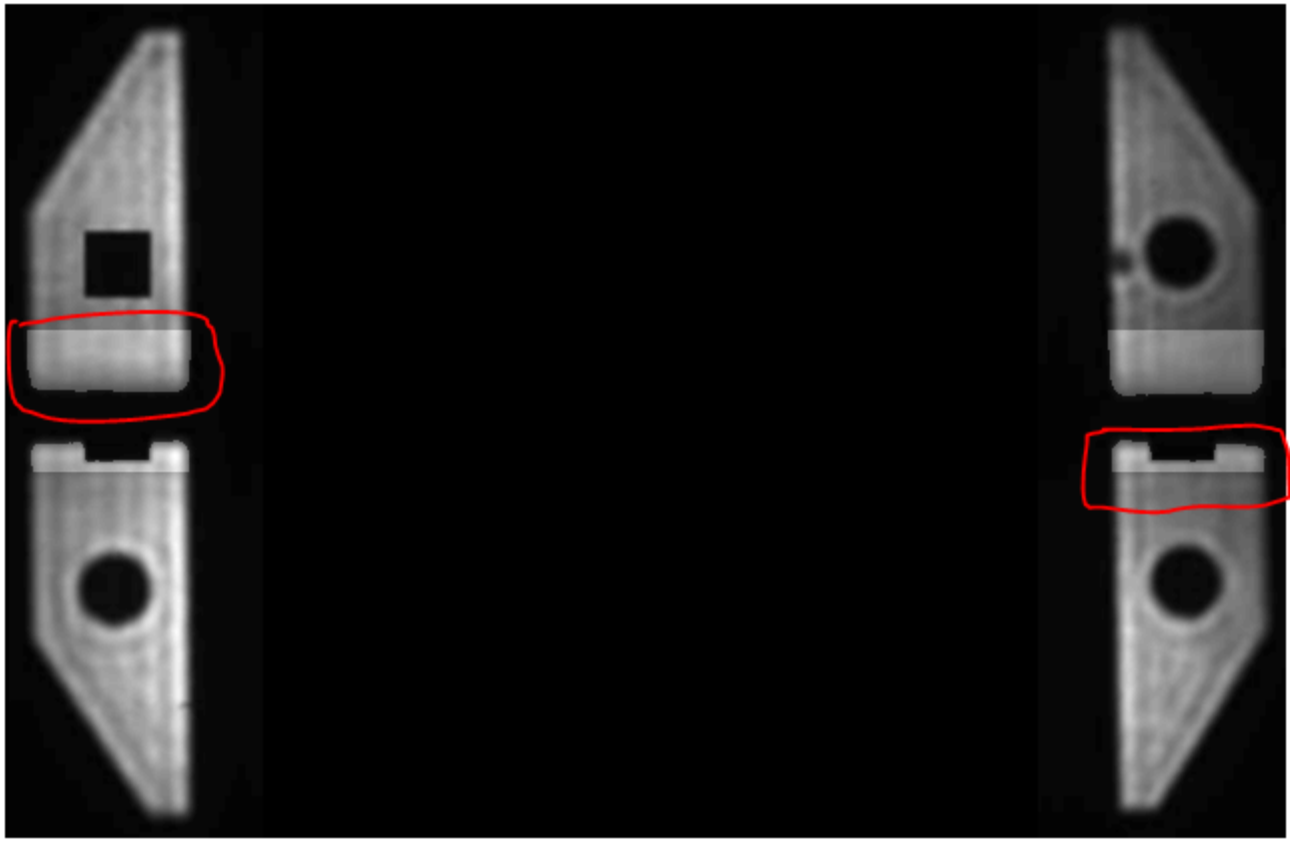


Subimaging to enhance processing using local stats

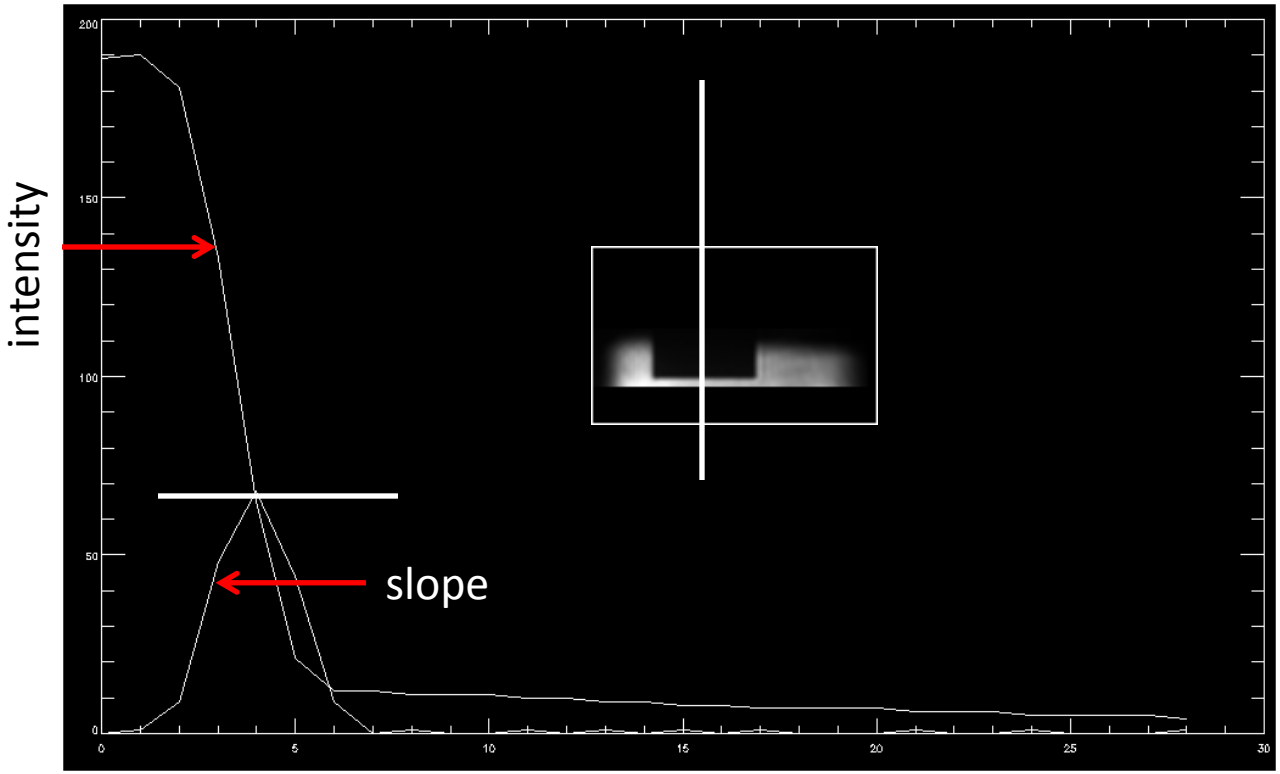




Binarize using local statistics



Analyze edge to select threshold



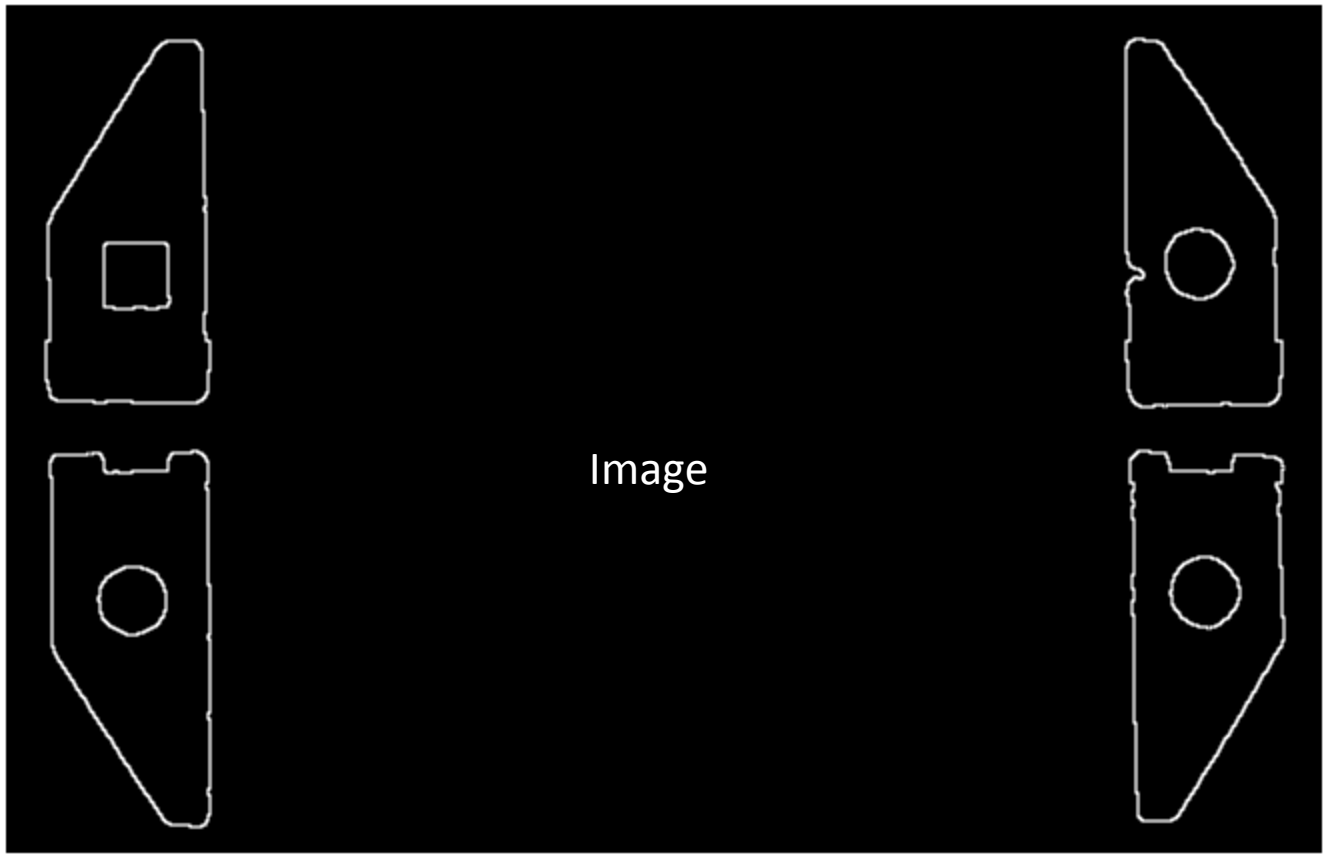
Estimate fiducial sizes using binarized image

Finding sizes using binary image

Four x and y values 30 ,1016 and 379 ,1034
The size of the truncated image is 987 x 656

Blob classification based on size on binary images..
Looking for features in the range 600.625 to 3363.50
Feature sizes of interest 1722 1617 2542 2056
Found 4 spots in the valid range
For blob 1722, x = 915.00 y = 196.00 sq_side = 41.50 or rad = 23.41
For blob 1617, x = 81.00 y = 202.50 sq_side = 40.21 or rad = 22.69
For blob 2542, x = 77.50 y = 444.00 sq_side = 50.42 or rad = 28.45
For blob 2056, x = 913.50 y = 451.50 sq_side = 45.34 or rad = 25.58
Searching for square around 77.5000 444.000
Searching for big circles at 81.0000 202.500
Chosen Circle radius = 22.5000 Chosen Square side = 24.5000

Calculate fiducial positions using edge image and feature model



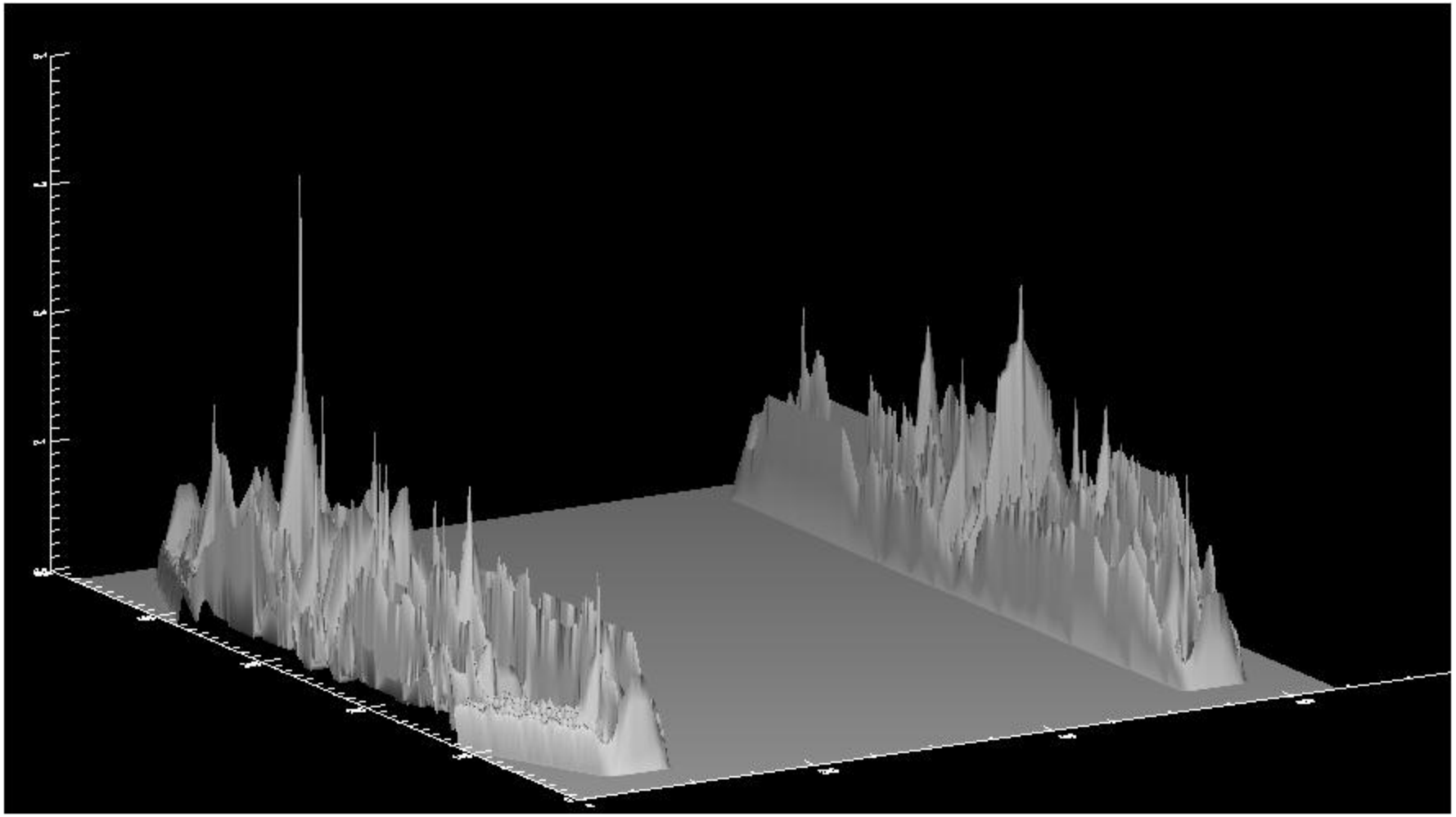
template

Increases the correlation peak by more than 10%

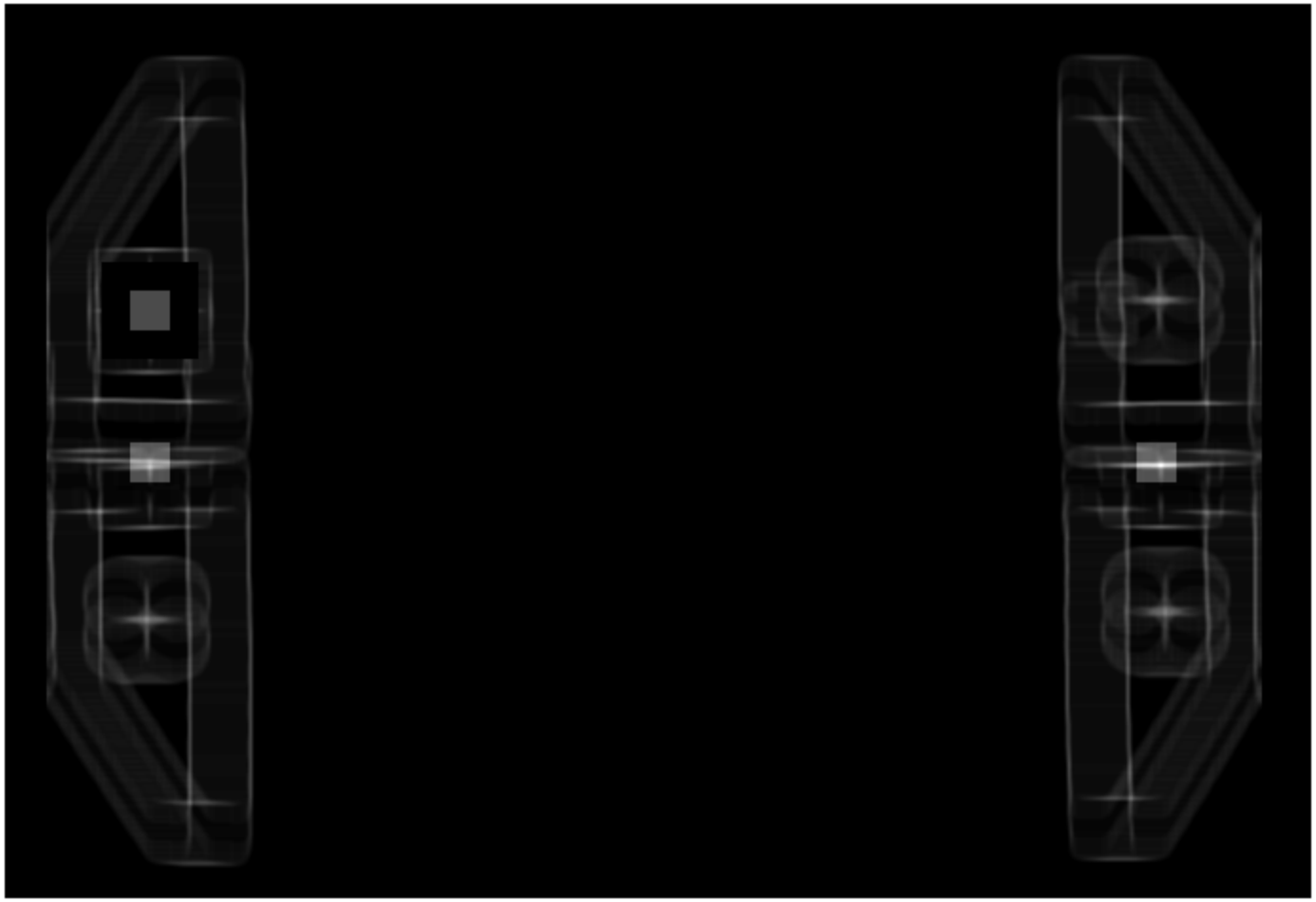
Detecting Squares using matched filtering

template

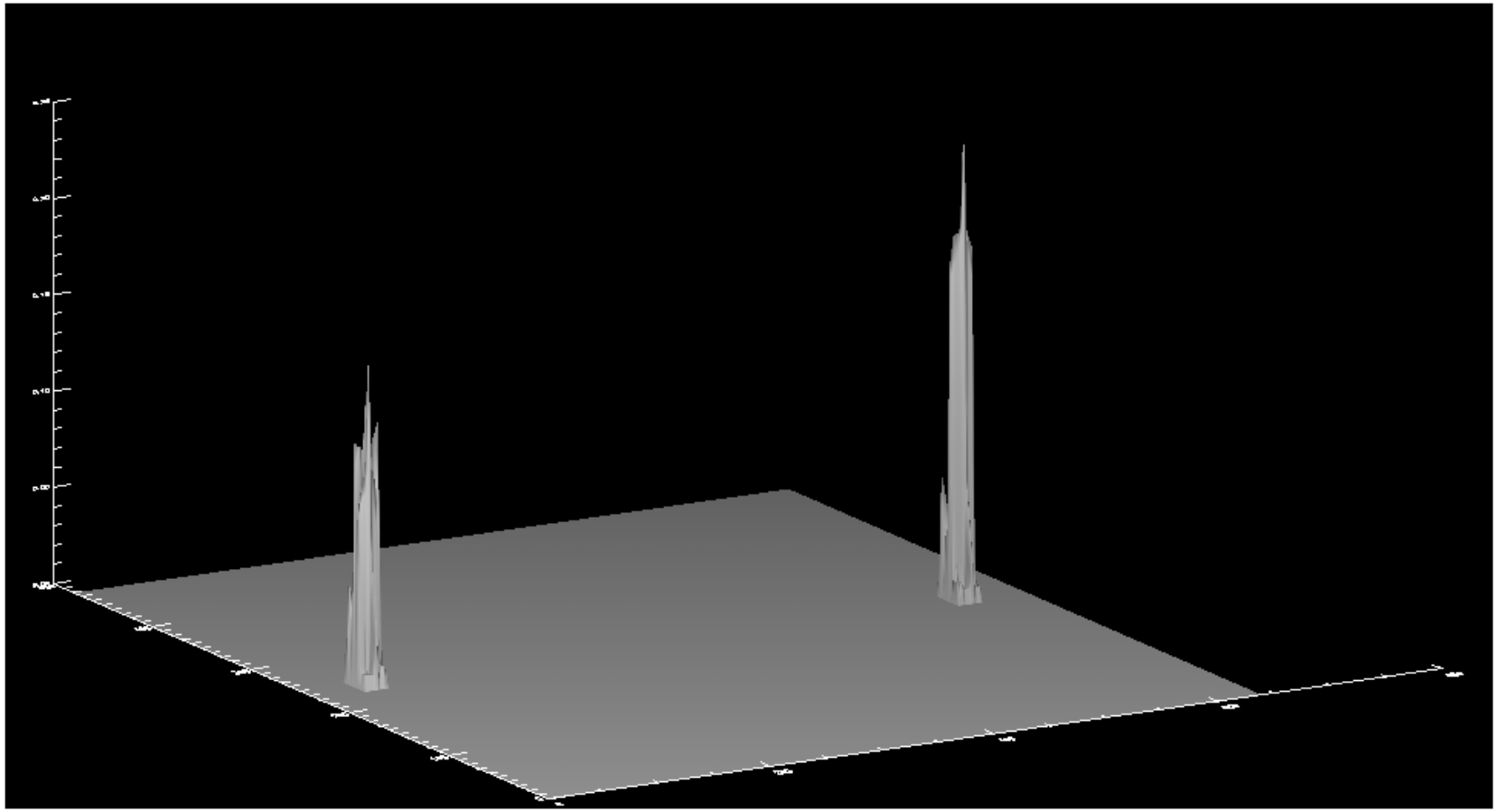
Detecting strongest peaks by masking



Generate Mask using top left position



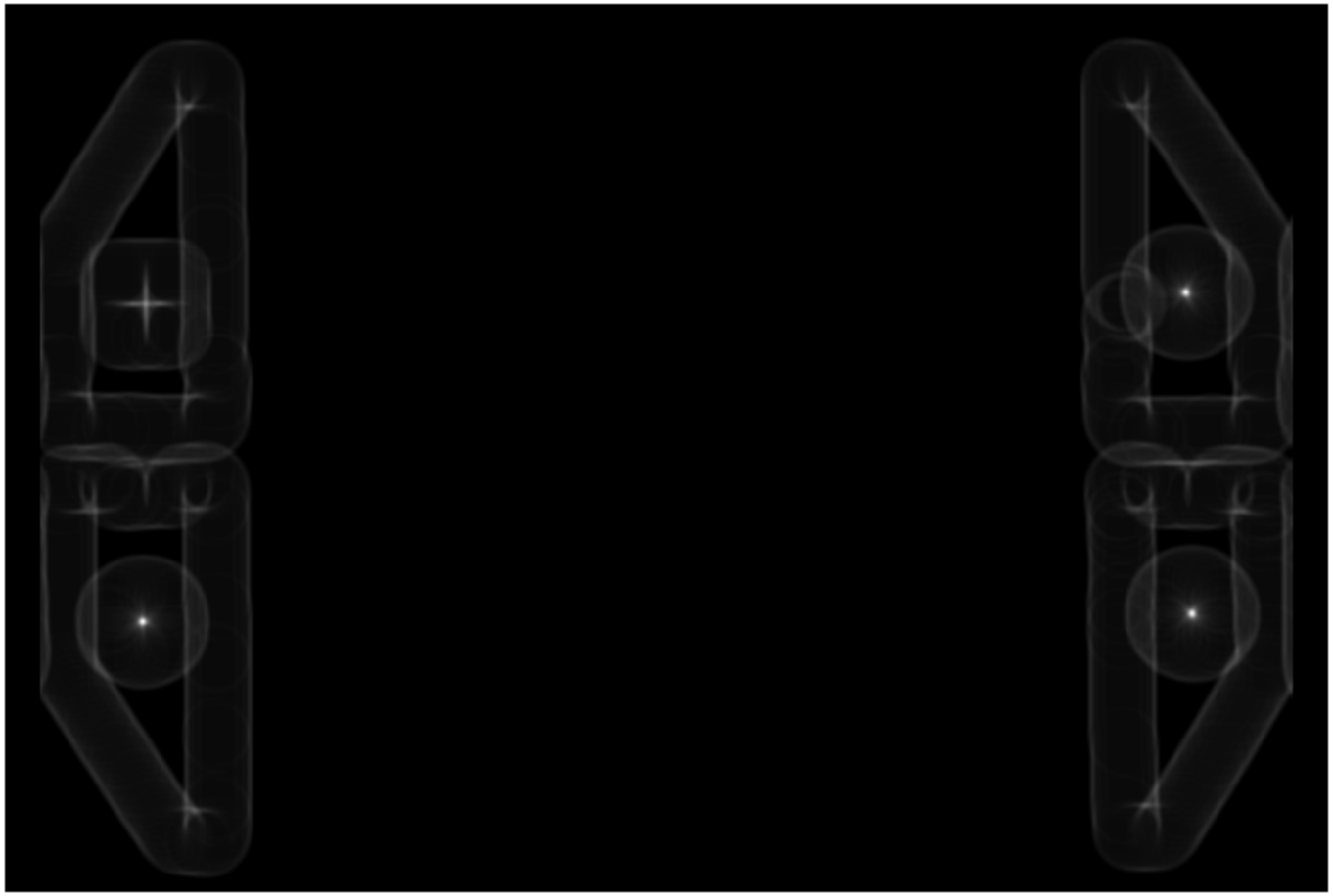
Masking in correlation plane



Finding position using edge

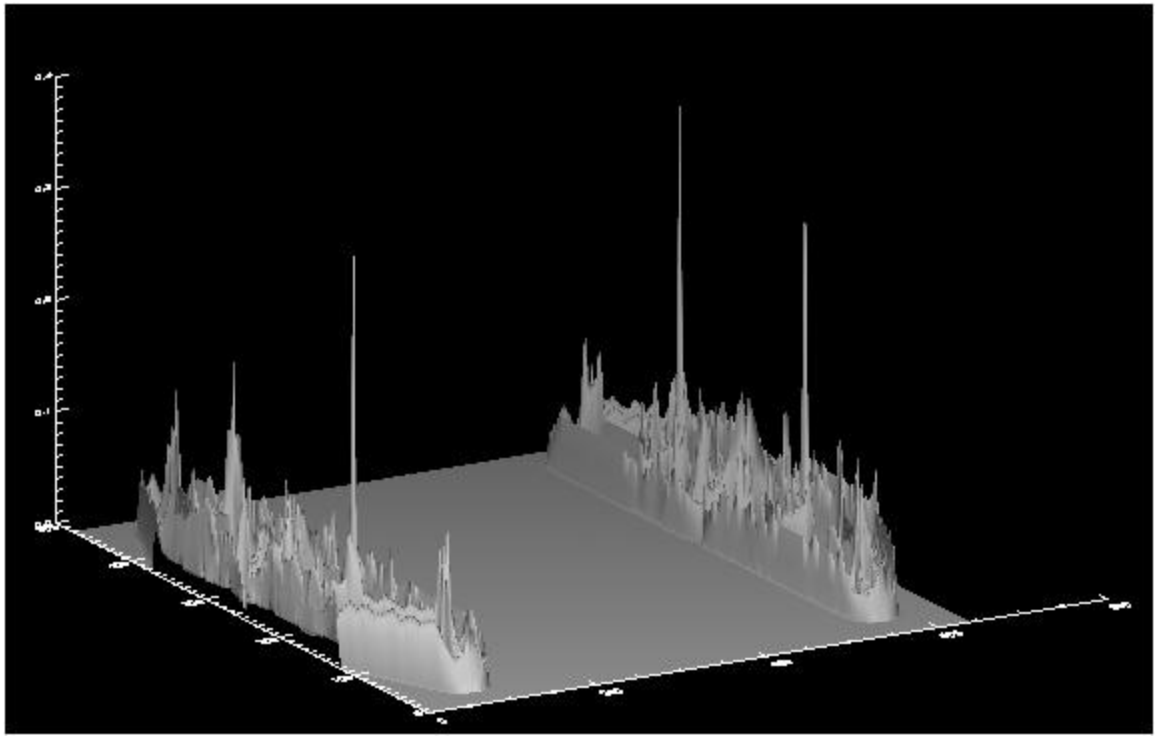
Looking for the outer squares with dimension 24.5000
xpos = 77.56, ypos = 444.14 Quality = 1.00 spots = 1
Top left square found, now creating mask...
xpos = 903.87, ypos = 316.99 Quality = 0.57 spots = 2
xpos = 77.94, ypos = 315.60 Quality = 0.47 spots = 3
*********Minimum quality factor accepted = 0.300000 and present 0.468889

Detecting circles using matched

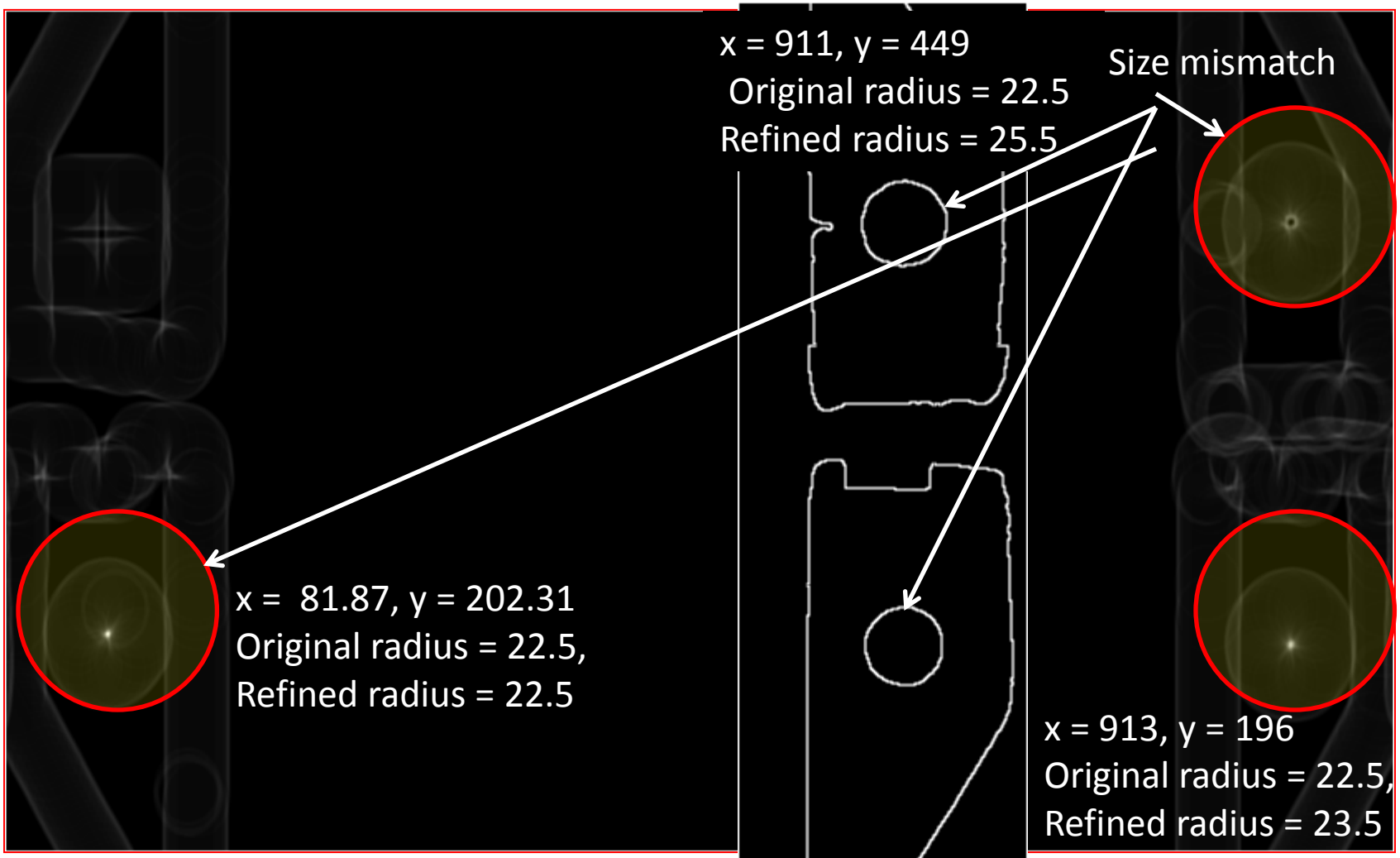


One size template detects all three circles

Peaks selected for circle locations



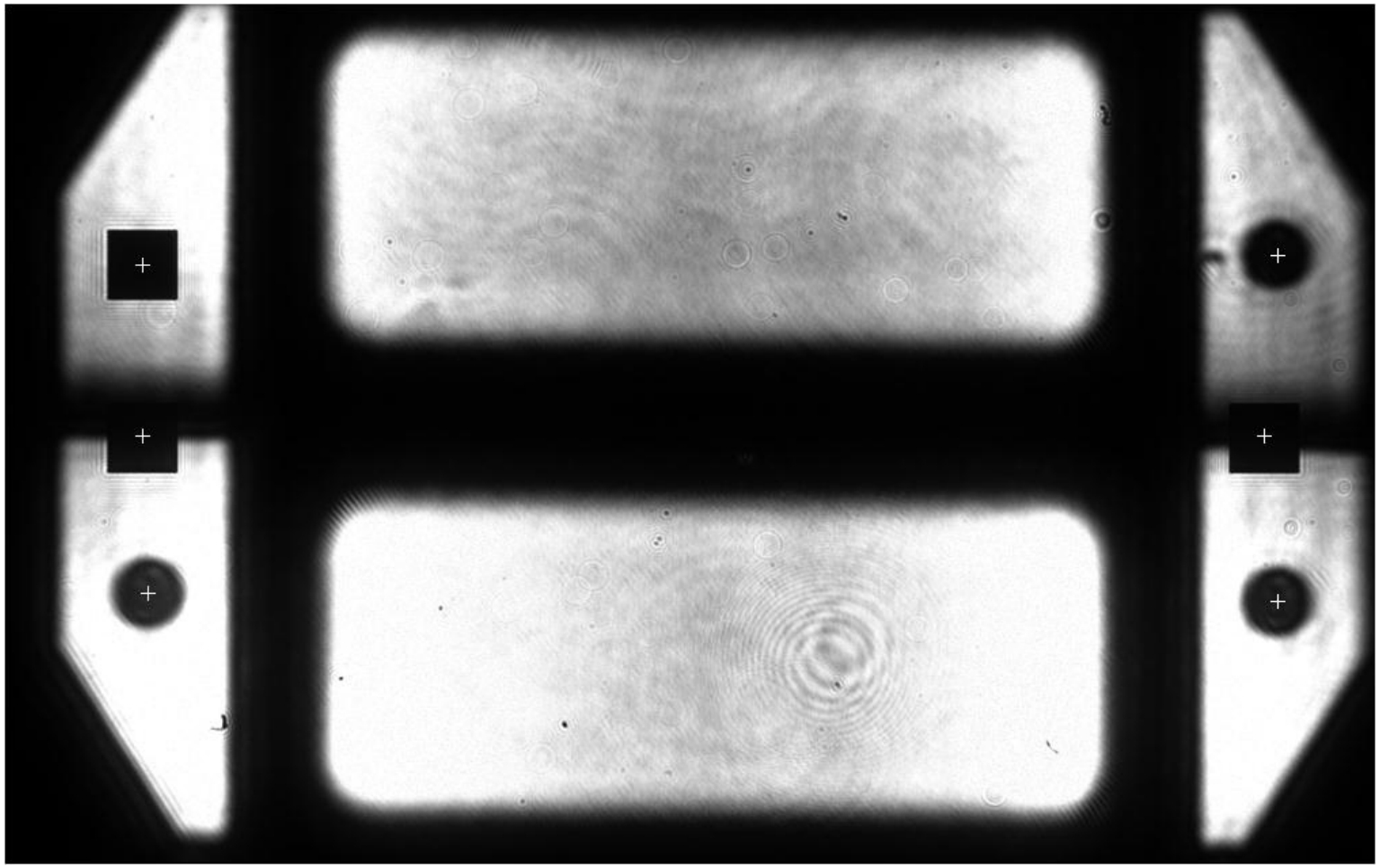
Differing sizes are detected by size refinement



Refining the circle size

Looking for the outer circles with radius 22.5000
xpos = 81.88, ypos = 202.30 Quality = 1.00 spots = 4
Original radius = 22.5, Refined radius = 22.5
xpos = 913.81, ypos = 195.92 Quality = 0.81 spots = 5
Original radius = 22.5, Refined radius = 23.5
xpos = 910.86, ypos = 448.78 Quality = 0.42 spots = 6
Original radius = 22.5, Refined radius = 25.5
*********Minimum quality factor accepted = 0.500000 and present
0.422914
Possible 3 squares and 3 circles found.....

Final positions after refinement



Triple Error check is performed to assure reliability

- Interspot distances between circles (squares) (x-536, y=164, tol=50)
- Absolute position check (lower left, upper right etc.)
- Two spots taken at a time test (Diagonal circles – center squares)

Failure occurs if any of the tests fail !

Spacing check to ensure reliability

```
Looking for the circular spots with x_spacing      830.800 and y_spacing
     254.200 with tolerance 10-12%      83.0800      30.5040
Found       3 circle  spots after spacing test
Looking for the square spots with x_spacing      830.800 and y_spacing
     127.100 with tolerance 10-12%      83.0800      15.2520
Found       3 square  spots after spacing test
Passing manual position check ......
Passing redundant check for circles (2 at a time)...
Passing redundant check for squares (2 at a time)...
---------------------------------------------------------------------
Found       6 viable spots after triple  tests ...

arc_ref_squares_beam_circles_eh:
     111.875      581.301      1.99000
     943.837      830.133      1.99000
     107.937      694.596      1.99000
     933.866      695.987      1.99000
     107.563      823.145      1.99000
     943.908      574.942      1.99000
```

Algorithm solves two challenges

- Squares: partially missing features on two crucial object
- Circles: Variations in circle dimension